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Error Concealment For Slice Group Based Multiple Description Video Coding

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Abstract—This paper develops error concealment methods for multiple description video coding (MDC) in order to adapt to error prone packet networks. The three-loop slice group MDC approach of [9] is used. MDC is very suitable for multiple channel environments, and especially able to maintain acceptable quality when some of these channels fail completely, i.e. in an on-off MDC environment, without experiencing any drifting problem. Our MDC scheme coupled with the proposed concealment approaches proved to be suitable not only for the on-off MDC environment case (data from one channel fully lost), but also for the case where only some packets are lost from one or both channels. Copying video and using motion vectors from correct descriptions are combined together for concealment prior to applying traditional methods. Results are compared to the traditional error concealment method proposed in the H.264 reference software, showing significant improvements for both the balanced and unbalanced channel cases.

I. INTRODUCTION

Video transmission over lossy network is a challenging problem. In video compression, due to predictive coding, any bit loss can cause great quality degradation. Multiple description coding is one approach to address this problem, whereby several sub bit streams called descriptions are generated from the source video. Each description can reconstruct video of acceptable quality and all the descriptions together can reconstruct higher quality video.

Unlike layered video coding techniques, each description generated by MDC can be independently decoded and reconstructed with acceptable quality. This can give a graceful degradation of the received video with loss, while avoiding the catastrophic failure of layered coding due to loss of the base layer.

An MDC system consists of two kinds of decoders. One is the central decoder which is used when all the descriptions are received, and the other is the side decoder which just uses one or a subset of descriptions to reconstruct video of acceptable quality. More correlations in the descriptions will result in higher quality for the side decoded video. At the same time the central decoder must perform with lower efficiency because more redundancy is introduced. Extensive research on MDC in order to increase the efficiency has been conducted [2]-[9].

MDC based on Scalar Quantization is developed in [1] to divide a signal by two coarser quantizers, and it's applied to predictive video coding in [2]. The output of each quantizer is

the approximation of a single description. Any one description can use its coarse data to generate a basic video and both of them can be combined to reconstruct higher quality video. Another approach on image coding is addressed in [3] using pairwise correlating transforms to transform a vector of DCT coefficients into another vector of correlated components, which introduces additional correlations between components. This was used in motion compensated video coding [4]. A spatial approach to generating MDC is proposed in [5] through pre- and post-processing. Redundancy is introduced by padding zeros in the frequency domain which results in more correlations. After this processing the video is sub-sampled into two descriptions. The two descriptions are independently coded at the encoder. In temporal scheme of [6], video sequence is divided into two by means of odd and even frames and different concealment methods are used to estimate lost frames. In [7] odd and even frames compose two descriptions, which is similar to [6], but three motion compensation (MC) loops are maintained. It performs well on on-off MDC environments and packet lossy network. But it can only use previous two frames as reference with constant weights of two motion vectors. In [8] we have proposed another spatial approach based on the slice group coding tools of H.264. Two slice groups compose the main information in two descriptions respectively. One of the slice groups is encoded very coarsely to maintain basic information as redundancy. It performs very well having good error resilient properties, but in order to keep the required central quality, it has the restriction of fixed quality setting for the main slice group, hence not so flexible in terms of controlling redundancy and results for low bitrate are not good. Further work is done in [9], where three MC loops are maintained, as in [7]. It has no restriction to the number of reference frames. In each side encoder, there is one slice group coded based on the stream from the central encoder, while the other slice group is coded independently with coarse quality. It is much more flexible than [8], and has better quality with the same redundancy settings.

Most of above MDC schemes contain two descriptions and mainly target the “on-off” channel scenario, under the assumption that multiple independent channels are either error-free or temporarily down. In such an environment, MDC can perform well and the decoded quality is that of the side results generated from just one description. But if the channel experiences packet losses or has burst errors, each

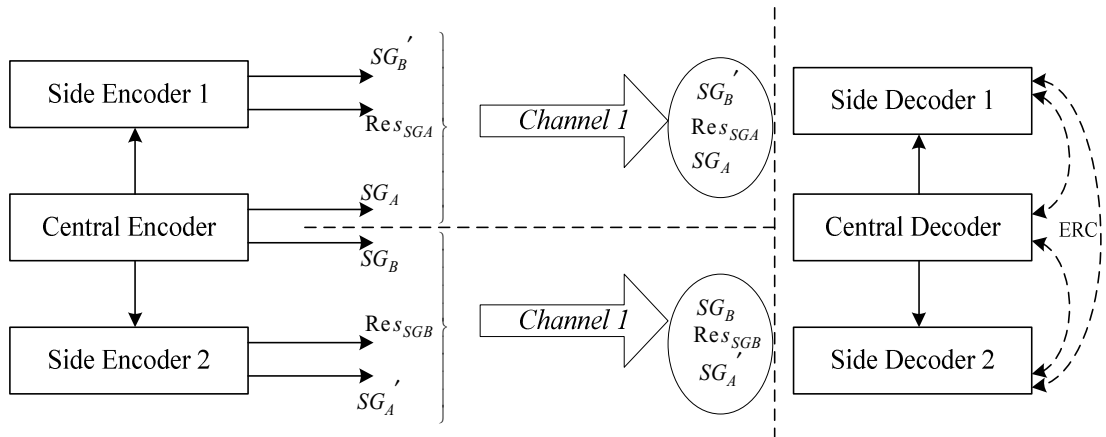


Figure. 2 Structure of the SG MDC scheme and transmission

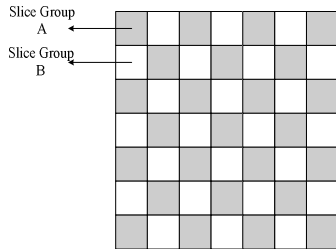


Figure. 1 Macroblock Map For Dispersed Slice Group

description may not be good but at the same time not totally useless, hence the results will not be as good as expected. Traditional error concealment methods can be used, however they cannot exploit useful information available across descriptions.

In this paper, we propose a scheme based on [9] (3 loop slice group based MDC, SG MDC) which enhances the performance of SG MDC in packet loss environment, by applying error concealment specifically for MDC together with a more traditional error concealment method. The proposed method provides more accurate motion information and better results for burst errors, without adding further redundancy to the existing MDC, which has been shown to perform very well in an on-off MDC environment [9].

The rest of this paper is organized as follows. In Section 2 our slice group based MDC is described. Section 3 gives the results and analysis of experiments. Conclusions are presented in section 4.

II. SG MDC AND ERROR CONCEALMENT

Slice Group is a new coding tool in H.264. The picture is divided into slice groups and it can be further divided into slices in scan order. There are totally 7 types of macroblock allocation for slice group, i.e. slice group map types, in which type 1 is called 'dispersed' slice group map. For two slice groups A and B (SG_A and SG_B), macroblock allocation map is as in fig. 1, which is like a checkerboard. It is very effective

for error concealment, and two slice groups are chosen as the basis of our MDC scheme. The basic idea of SG MDC is that, in each description, only one slice group is finely encoded, and the other slice group is encoded coarsely to keep basic information.

As in [9], SG MDC consists of 3 encoders of which one is the central encoder and the others are side encoders. The central encoder is the same as a single-description standard encoder. Two descriptions are generated of which one description contains data from one side encoder and part of the central encoder. If two descriptions are correctly received at the decoder side, data generated from the side encoder is just redundancy and data from the central encoder is fed into the standard decoder. If one description is lost, the corresponding side decoder is used to decode the received description. It is obvious that the two descriptions are symmetric and the two side decoders are independent from each other. Any of them can reconstruct video without any drift problems by itself. This scheme is proved to be of good performance and is very flexible [9]. In the following we will analyze the decoding activity for packet based networks.

As we can see from Fig. 2, in which the coder details are ignored, the central encoder generates SG_A and SG_B which form the standard bitstream similar to single description coding. Side encoder 1 outputs SG'_B which is normal stream of SG_B with coarse quality used for maintaining the side MC loop, and Res_{SGA} which contains a small amount of residuals for SG_A coded based on the central coding data. This maintains efficient MC loop and will be used when burst errors occur. The side encoder 2 is symmetric to side encoder 1. These data is divided into two groups as in fig. 2 and are transmitted into two separate channels. SG'_B and SG'_A contain completely independent sets of motion information and residual data, and they can be utilized to enhance error concealment.

To make the problem simpler, we will focus on loss of SG_A in central decoding. Our concealment method is applied prior to traditional H.264 software concealment. Only the MBs

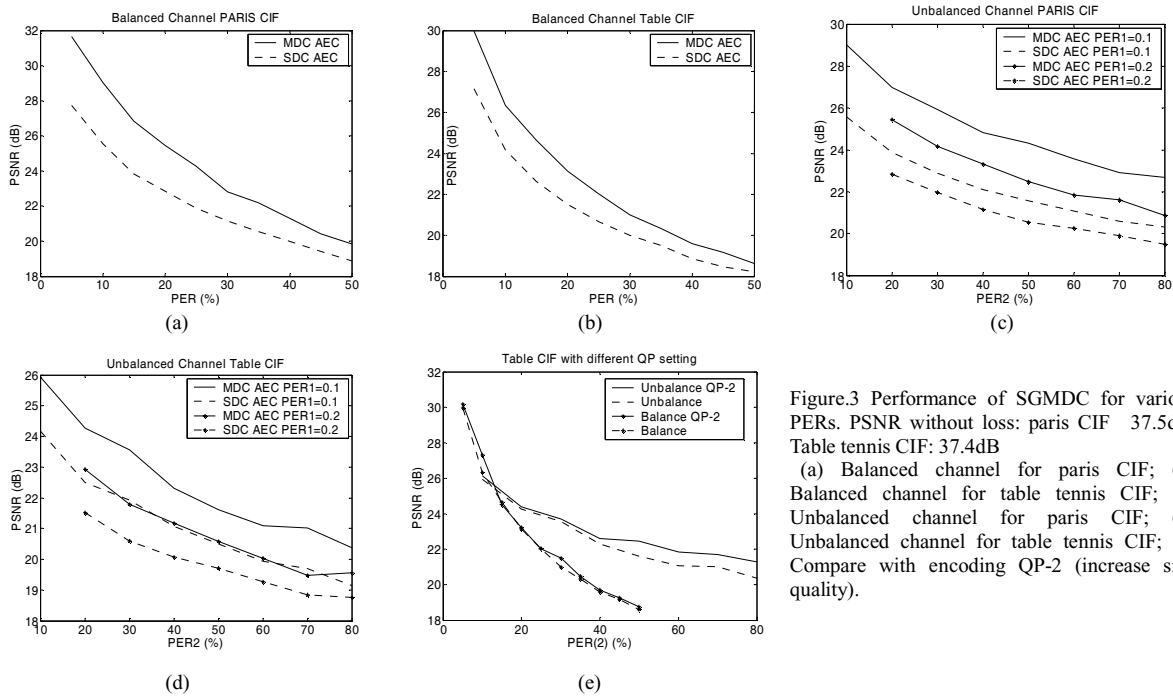


Figure 3 Performance of SGMD C for various PERs. PSNR without loss: paris CIF 37.5dB. Table tennis CIF: 37.4dB
 (a) Balanced channel for paris CIF; (b) Balanced channel for table tennis CIF; (c) Unbalanced channel for paris CIF; (d) Unbalanced channel for table tennis CIF; (e) Compare with encoding QP-2 (increase side quality).

which cannot be concealed by our scheme are concealed using traditional methods.

If one MB in SG_A is lost, the following scenarios apply.

- 1) The corresponding MB in SG'_A is correctly received.
 - If it is inter-coded, we use the corresponding motion information to recover SG_A in the central decoder.
 - If it is intra-coded, a mode decision based on the boundary matching algorithm of H.264 [10] is made which chooses one of the following options:
 - a) Copy MB in SG'_A to the lost position in SG_A .
 - b) Conceal with H.264 temporal concealment using $mv=0$ (if it is not the first frame)
- 2) The corresponding MB in SG'_A is corrupted too.
 - In this case, nothing is done and traditional concealment is applied instead.

If there are burst errors in channel 1 over two frame's time for one area, the correctly reconstructed video data from channel 2 will be copied to both the central decoder and side decoder 1. These data are the side results according to the reference buffer in side decoder 1. The quality is affected by the side encoding parameters. This is similar to methods with an on-off MDC environment.

Hence, after finishing with concealments (proposed and traditional), lost areas in side decoder 1 are concealed. As a result, for non-burst error areas, the SG_A in side decoder 1 is concealed by copying video data from the central decoder, and SG_B is concealed using traditional methods. The reason why we do not copy data from the central decoder to the SG_B of the side decoder 1 is because this was found to give worse results compared to using temporal error concealment.

The advantage of applying our additional error concealment prior to the traditional one is that the motion vectors are more accurate, and in case of an intra coded MB, the mode decision results are also better. With our error concealment approach, the SGMD C is capable of combating both on-off MDC environment and packet based network environments with burst error and/or packet losses.

III. RESULTS AND ANALYSIS

We examine the performance of our SGMD C in a packet based network. Results for on-off MDC environment can be found in [9]. Packets are generated with 22 macroblocks per slice, i.e., per packet. For all the cases, we use the video coding standard H.264 [11] as the basic coder. The error concealment method in H.264 [10] is used, which is named 'AEC' here. Fixed frame rate (30 frames/second) and constant quantizer step size are used for each slice in all frames of the test sequences. No B frames are used. Sequences 'paris' and 'table tennis' of CIF format are coded. The three sets of encoders and decoders are communicating with each other in real time, through windows programming. Simulations are run 100 times for each packet loss rate (PER) value.

There are basically two kinds of settings for the two channels. One is balanced channels for which the PERs are the same for each channel, and the other is unbalanced with different channel PER. The results for balanced channels are presented in fig. 3 (a) and (b). It's obvious that our method (MDC AEC) is better than traditional methods (SDC AEC). The improvements vary in range from 1 to nearly 4dB. Note that for small PERs, the improvements are bigger. With high PERs, both MDC and SDC methods cannot do well in error concealment with so many packets lost. Main reason for the improvements is the use of more accurate motion vectors.

Some MBs may be coded in intra mode because of too complex motion, in which case copying data from the correct channel through mode decision may bring better results too. Performance results for unbalanced channels are shown in fig. 3 (c) and (d). When the difference between the PERs of the two channels is small, the behaviour is similar to the balanced channel case. When this difference becomes large, frequent loss of frames occurs in the bad channel, in which case copying video from the good channel starts to show its advantage.

As in [9], SGMDC can adjust its encoding parameters to change redundancies, in order to achieve different quality results. This affects the decoding performance too. Fig. 3 (e) shows how this influences our decoder. We increase redundancy to get better qualities of SG_B' and SG_A' through decreasing QPs by 2. For balanced channels, the effect is not obvious, because motion vectors are the main contributors. However in unbalanced channels, this further improves the quality of decoded video especially for higher PER2, since copying data from the side decoders is employed more frequently.

Fig.4 shows a comparison of decoded pictures of frame 95 for the *paris* sequence for various PER settings. The left side shows results from MDC error concealments. The right side is for the SDC error concealments. In all cases, visual improvements are significant. With unbalanced channels and a high loss rate, this becomes more obvious. It should be noted that similar results were observed for other sequences.

IV. CONCLUSIONS

In this paper we proposed error concealment methods suitable for MDC coding approach [9]. Concealments suitable for MDC are done besides traditional H.264 error concealment. By considering packet loss statistics and coding modes of detailed macro blocks, either motion vectors are used or video from the correct channel is copied to recover lost areas. With our scheme on decoder, the MDC codec is suitable for on-off MDC environments, packet loss network environments, and mixture of them. It is shown through simulations that our scheme performs very well and is better than the traditional approaches.

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(a)



(b)



(c)



(d)

Figure 4. Comparison of results between MDC (left) and SDC (right) error concealment: (a) PER1/2 = 0.1 (b) PER1/2 = 0.3 (c) PER1 = 0.1 PER2 = 0.3 (d) PER1 = 0.1 PER2 = 0.7

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